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MEASUREMENT OF $d\sigma/dy$ FOR HIGH MASS DRELL-YAN e^+e^- PAIRS AT CDF

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We report on the first measurement of the rapidity distribution $d\sigma/dy$ over nearly the entire kinematic region of rapidity for e^+e^- pairs in the Z-boson region of $66 < M_{ee} < 116$ GeV/c^2 and at higher mass $M_{ee} > 116$ GeV/c^2. The data sample consists of 108 pb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV taken by the Collider Detector at Fermilab during 1992–1995. The total cross section in the Z-boson region is measured to be 252 ± 11 pb. The measured total cross section and $d\sigma/dy$ are compared with quantum chromodynamics calculations in leading and higher orders.

Most measurements at high energy proton-antiproton colliders are performed in the central rapidity production region, $|y| < 1$. A model dependent extrapolation for $|y| > 1$ is needed to extract the total cross section for hard processes such as top quark production or W and Z boson production. This extrapolation is made using Monte Carlo programs (e.g. PYTHIA, which incorporate quantum chromodynamics (QCD) calculations in leading order (LO) or next to leading order (NLO). A previous measurement of the rapidity distribution, $d\sigma/dy$, for dimuon pairs in the Z-boson mass region was limited to $|y| < 1$. In this communication, we present the first measurement of $d\sigma/dy$ for e^+e^- pairs in the Z-boson mass and high mass region over nearly the entire kinematic region of rapidity. At the Tevatron $p\bar{p}$ collider, the kinematic limit at the Z-boson mass is $|y| = 3.0$, while we measure $|y|$ up to 2.8. The $d\sigma/dy$ distributions are compared to the predictions of QCD in LO and NLO. This measurement is also relevant for precision W boson mass measurements at hadron colliders, where W's are reconstructed using $e\nu$ and $\mu\nu$ pairs from the Drell-Yan process.

In hadron-hadron collisions at high energies, massive e^+e^- pairs are produced via the Drell-Yan process. In the standard model, quark-antiquark annihilation form an intermediate γ^* or Z (γ^*/Z) vector boson, which then decays into an e^+e^- pair. In LO, the momentum fraction x_1 (x_2) of the partons in the proton (antiproton) are related to the rapidity, y, of the boson via the equation $x_{1,2} = (M/\sqrt{s})e^{\pm y}$. Here s is the center of mass energy, and M is the mass of the dilepton pair. Therefore, dilepton pairs which are produced at large rapidity originate from events in which one parton is at large x and another parton is at very small x. Since the quark distributions for x up to 0.9 are well constrained by the deep-inelastic

lepton scattering experiments, comparisons of data and theory for $d\sigma/dy$, and the total cross sections provide a test of the theory, e.g., missing NNLO[1] or power correction terms.

The e^+e^- pairs are from 108 pb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV taken by the Collider Detector at Fermilab (CDF) during 1992–1993 (18.7 ± 0.7 pb^{-1}) and 1994–1995 (89.1 ± 3.7 pb^{-1}). In a previous letter, we presented $d\sigma/dP_{\rm T}$ of Z boson using has three categories of e^+e^- pairs: central-central (CC), central-end plug (CP), and central-forward (CF). This analysis extends the sample to the forward rapidity region by including plug-plug (PP) and plug-forward (PF) events. The inclusion of these events increases the event sample by 20% and allows for measurement of Z bosons with $|y|$ up to 2.8. An improvement in this analysis is the additional VTX tracking requirements for plug and forward electrons. The VTX covers the entire rapidity range in this study, and plays an important role in removing background in the high η region which is not covered by the CTC.

The data sample is divided into two mass bins: the Z region ($66 < M_{ee} < 116$ GeV/c^2) and the high mass region ($M_{ee} > 116$ GeV/c^2). After all cuts, the numbers of CC, CP, CF, PP, and PF events in the Z mass region are 2894, 3811, 621, 1236, and 589, respectively. The backgrounds are low and are estimated using the data. The PP+PF events extend the acceptance of the y measurement to $|y| = 2.8$, and significantly increase our statistics by extending the acceptance beyond $y > 1.2$.

Figures 1(a) and 1(b) compare the measured $d\sigma/dy$'s to theoretical predictions in the Z mass and high mass regions, respectively. The top horizontal axes on these figures are the corresponding values of the x_1 and x_2 as a function of y. The predictions are LO calculations with CTEQ5L PDFs and NLO calculations with MRST99 and CTEQ5M-1 PDFs. The predictions in Figure 1(a) have been normalized by a factor "F", the ratio of measured total cross section to the prediction (F=1.51, 1.14, and 1.13 for the CTEQ5L, MRST99 and CTEQ5M-1 PDFs, respectively). The predictions in Figure 1(b) are normalized to the data using the factor F from the Z mass region. As the χ^2 values listed in Figure 1(a) indicate, the LO calculation using recent LO PDFs does not fit the shape as well as the NLO calculation with the most recent NLO PDFs.

Model independent measurements of the total production cross sections for e^+e^- pairs are extracted by integrating the measured values of $d\sigma/dy$. The extracted cross section in the Z mass region is $252.1 \pm 3.9\,(\text{stat.}) \pm 1.6\,(\text{syst.}) \pm 9.8\,(\text{lum.})$ pb. The corresponding $\sigma(p\bar{p} \to Z) \cdot Br(Z \to ee)$ is $253 \pm 4(\text{stat.} + \text{syst.}) \pm 10(\text{lum.})$ pb. The total cross section measurements can also be compared to QCD calculations. Fixed order QCD calculations have uncertainties from PDF measurements and corrections from higher orders of perturbation theory, i.e., the K-factor. The NLO-to-LO total cross section correction is significant: $K \sim 1.4$. In contrast, the NLO total cross section is lower than NNLO prediction by only 2.3%. The NNLO prediction with the latest NLO MRST99 PDFs is 227 ± 9 pb, where the 4% error is mostly from uncertainties in the NLO PDFs. Although a full set of NNLO PDFs is not available, recent estimates of NNLO PDFs indicate[1] that the NNLO PDFs will increase the

theoretical cross sections by $1-4\%$ (e.g. MRST00(NNLO) PDF yields 230 ± 9 pb) Given these uncertainties, the theoretical expectation is consistent with the Z cross section measurements. The measurement of the Drell-Yan total cross section in the high mass region is $4.0 \pm 0.4\,(\text{stat.} + \text{syst.}) \pm 0.2\,(\text{lum.})$ pb. The corresponding prediction of the total cross section from the NNLO QCD theory using MRST99 PDFs is 3.3 pb. Additional details on this work can be found in Reference 2.

References

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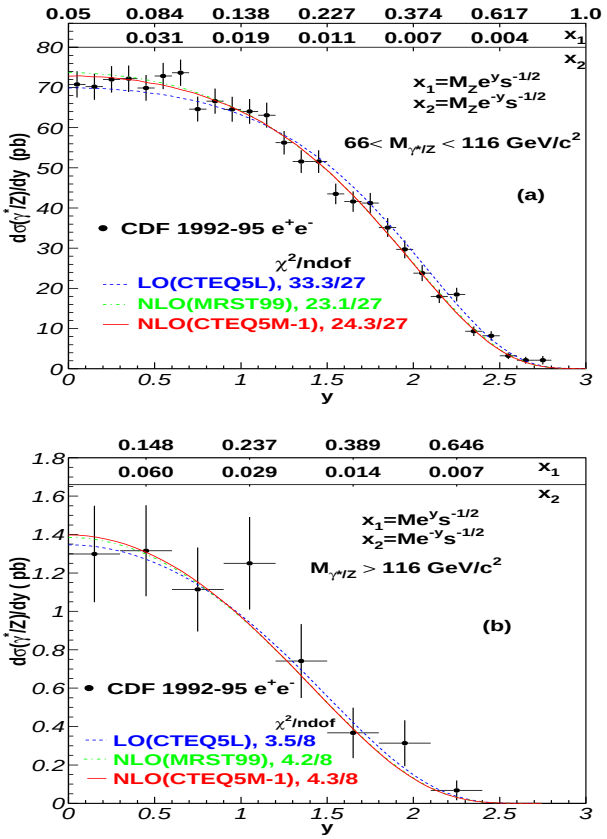

Fig. 1. $d\sigma/dy$ distribution of e^+e^- pairs: (a) in the Z boson mass ($66 < M_{ee} < 116$ GeV/c^2) region. (b) in the high mass ($M_{ee} > 116$ GeV/c^2) region. The M used to obtain x_1 and x_2 in (b) is the mean mass over the bin. The error bars on the data include statistical errors only. The theoretical predictions have been normalized to the data in the Z boson mass region.